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NUEXCO

DECEMBER 1986 NUMBER 220

MONTHLY REPORT

ON THE NUCLEAR FUEL MARKET

NUEXCO

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MONTHLY REPORT ON THE NUCLEAR FUEL MARKET

December 1986 No. 220

R. WESLEY MILLER, *EDITOR* CHARLES B. LEWIS, *ASSISTANT EDITOR*

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To Our Readers

We are pleased to announce that **Mr. Charles B. Lewis** has joined Nuexco to assist Wes Miller with the production of the Monthly Report. Charlie has over ten years of experience in technical writing and engineering, and in the early 1970s served in the Peace Corps in Thailand. He holds a B.A. in English Literature from Lewis and Clark College and an M.A. in East Asian Studies from Stanford University, and speaks Chinese, Thai, and Spanish. He will be relieving Clark Beyer, who will be involved in brokerage operations in the USA and Canada. Clark has been the Associate Editor of the Monthly Report for the past two years.

* * *

Beginning in this issue of the Monthly Report, we are adding European Currency Units (ECU) to the tables showing the Nuexco Market Values expressed in selected producer and consumer currencies. The ECU is a composite currency of the ten national currencies of European Economic Community nations. In 1979, the EEC members formed the European Monetary System, and designated the ECU as its official currency.

The ECU is formed by incorporating fixed percentages of each currency — for example, the West German Deutschemark comprises 32.24 percent of the ECU composite. The relative weight carried by each currency can also vary depending on the exchange rates of the individual units. On a daily basis, the EEC estimates ECU value against the various member currencies, as well as against the US dollar and Japanese yen.

* * *

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NATURAL URANIUM AND SECONDARY MARKET CONVERSION

(All data as of November 30, 1986)

The **Exchange Value** is **$16.75** per pound U_3O_8, down $0.25 since last month. **Active supply** of nautral uranium (concentrates and UF_6) for spot or near-term delivery totals **4,530,000** pounds U_3O_8 equivalent, up 790 thousand pounds since last month. The corresponding figure for **active demand** is **770,000** pounds, down 180 thousand pounds. The spot and near-term **supply-demand ratio** increased to **5.9:1.**

The *Current Market Data* section of this Report lists six natural uranium sales, involving approximately 750 thousand pounds U_3O_8 equivalent in the near term and five million pounds U_3O_8 equivalent in the longer term. Five of the transactions involved spot or near-term delivery, and four met the criteria for inclusion in the current Transaction Value calculation. Four of the transactions involved natural UF_6.

The **Transaction Value** is **$17.30** per pound U_3O_8, up $0.05 since last month. The calculation extends over a 3-month period and includes 13 transactions involving 2.0 million pounds equivalent U_3O_8.

The **UF_6 Value** is **$48.00** per kilogram U in UF_6, unchanged since last month.

The **Conversion Value** is **$1.80** per pound U in UF_6, down $0.10 since last month. Active supply of secondary market conversion services for delivery within three years totals 1.4 million pounds U as UF_6. Active demand totals 650 thousand pounds U as UF_6. One secondary market conversion transaction is reported.

The **Loan Rate** is **4 percent** per annum, unchanged.

* * *

The Exchange Value declined $0.25 to $16.75 this month. During November some sellers demonstrated a willingness to drop below $17.00 in their asking prices, and one transaction involving a relatively large quantity of non-US concentrates was concluded at a price near the current Exchange Value. Demand for natural uranium concentrates remained thin, declining about 20 percent since October to less than 800 thousand pounds equivalent U_3O_8. Sellers are also offering more natural uranium than last month. Supply increased by 20 percent, so the supply/demand ratio increased from 3.9 to 5.9.

The market for natural UF_6 was stable during November, and the UF_6 Value remained unchanged at $48.00. Overall, demand for UF_6 is somewhat greater than demand for U_3O_8, and significant quantities of non-US UF_6 are still available at prices around $48.00.

The market for uranium continues to reflect the uncertainties surrounding the lawsuit filed by three US producers against DOE. Although some observers had expected a ruling from the Tenth Circuit Court of Appeals to be handed down by the end of November, no such ruling has yet been made. Rumors that the court's ruling will be favorable to US producers appear to be partly responsible for the increasing competition among sellers, chiefly Canadian producers. As a result, significant quantities of natural uranium concentrates are being offered for sale at or below $17.00. Pending a resolution of this lawsuit, most discretionary buyers remain unwilling to commit to additional purchases at this time.

A letter from several members of Congress to President Reagan has refocused attention on the issue of how the US ban on the importation of South African uranium will be implemented. Because the law refers only to uranium oxide and uranium ore, some have argued that a literal interpretation would allow the importation of UF_6. However, the authors of the letter, including those members of Congress who sponsored the bill, emphasized that the legislation was clearly intended to prohibit the importation of any uranium of South African origin, regardless of form. South African origin UF_6 probably would have been included in the ban anyway, but the letter has made that result even more likely. The letter failed to address the question of whether the legislation would allow the importation of South African uranium solely for the purpose of processing and subsequent export to non-US utilities. Ultimately, the resolution of both issues will depend on the Reagan Administration's interpretation of the law. (For additional background on this issue, see page 16 of Report 218 [October 1986]).

The possibility of restrictions on the usage or enrichment of non-US origin uranium remains the most important single factor influencing the market. However, of the US utilities in the market or entering into transactions over the last several months, only about half specifically requested or ultimately contracted for US-origin material. Some US utilities have contracted for non-US uranium in order to feed it into the enrichment pipeline before possible limitations are enacted.

US-origin material currently commands a premium of $0.65 per pound U_3O_8 in the form of concentrates, and $2.50 per kilogram U in the form of UF_6. A few concentrate sales by US producers have included premiums near that amount, but most of the US-origin material sold in the last several months has been made available by means of origin-swap mechanisms. The utilization of such swaps has allowed US utilities to purchase US-origin material without having to pay most US producers' substantially higher asking prices.

* * *

The Conversion Value fell this month to $1.80, and demand remains thin. The secondary market remains largely inactive, as

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most buyers are not interested enough to rise to sellers' offers. Although supply of secondary market conversion services has declined slightly, one transaction was concluded at a level below last month's Conversion Value of $1.90.

* * *

ENRICHED URANIUM AND SWUs

The **SWU Value** as of November 30, 1986, is $80 per SWU, up $2 since last month. This refers to SWU at a tails assay of 0.30 weight-percent U_{235} and for delivery within one year. Three secondary market SWU transactions are reported this month, involving approximately 200 thousand SWU.

The three reported SWU transactions generally represent the range of opportunities available on the secondary market. Small quantities of DOE-origin virgin SWUs are still available at prices between $85-100. SWUs contained in enriched product generally are available in larger quantities, at prices near the current SWU value. The SWU market remains volatile, with variables such as delivery and notification dates, payment terms, and origin contributing to a range of SWU prices. In addition, many SWU opportunities now involve increasingly complicated displacement transactions or other mechanisms that can increase cost.

CURRENT MARKET DATA

November 30, 1986	Market Values	Active Supply[1] (thousands)	Active Demand[1] (thousands)
EXCHANGE VALUE	**$16.75**/lb. U_3O_8	4,530	770
UF_6 VALUE	**$48.00**/kgU		
CONVERSION VALUE	**$1.80**/lb. U as UF_6	1,415	650
SWU VALUE 0.3 tails assay; delivery within one year	**$80**/SWU		
LOAN RATE	**4%**/annum	0	0

	$/lb. U_3O_8	Millions of Pounds	Number of Transactions	Number of Months
TRANSACTION VALUE	**17.30**	2.0	13	3

[1]Supply and demand tables in *Current Market Data* section of this Report detail the numbers for each category.

DEFINITIONS

1. The **Exchange Value** is Nuexco's judgment of the price at which transactions for significant quantities of natural uranium concentrates could be concluded as of the date indicated.
2. The **UF_6 Value** is Nuexco's judgment of the price at which spot and near-term transactions for significant quantities of natural uranium hexafluoride could be concluded as of the date indicated.
3. The **Conversion Value** is Nuexco's judgment of the price at which spot and near-term transactions for significant quantities of conversion services could be concluded in the secondary market as of the date indicated.
4. The **SWU Value** represents Nuexco's judgment of the price at which transactions for the sale of significant quantities of SWUs of stated origin for delivery in the specified time period could be concluded as of the date indicated.
5. The **Loan Rate** is Nuexco's judgment of the annual interest rate at which uranium loans could be concluded as of the date indicated.
6. The **Transaction Value** is a weighted average price of recent natural uranium sales transactions. The calculation is based on prices paid in:
   a. Transactions closed within the previous three-month period for which delivery is scheduled within one year of the transaction date;
   b. At least ten transactions;
   c. Transactions involving a sum total of at least 2 million pounds U_3O_8 equivalent.

   The sample time is extended as necessary to include these minima. Other currencies are converted to US dollars using conversion rates in effect on or near the transaction date.

DERIVATIONS AND COMMENTS

1. All Market Values are based on:
   a. Data from recently completed transactions.
   b. Data from pending transactions.
   c. Firm bids to buy or borrow, and firm offers to sell or lend.
   d. Prices purchasers or rates borrowers have expressed a willingness to pay, but for which Nuexco is not aware of firm bids to buy or borrow, and prices sellers or rates lenders have expressed a willingness to accept, but for which Nuexco is not aware of firm offers to sell or lend.
2. Prices associated with deliveries under old or renegotiated contracts or other than arm's-length transactions are not included in the determination of these Market Values.
3. In the determination of the Conversion Value, Nuexco does not consider transportation charges other than those customarily provided by primary suppliers of conversion services.
4. The prices of conversion services or SWUs delivered under long-term contracts with primary suppliers are not considered in the determination of either the Conversion Value or SWU Value.
5. For the SWU Value, Nuexco converts SWU prices at varying tails and product assays to equivalent SWU prices at a tails assay of 0.30 weight-percent U_{235} and a product assay of 3.0 weight-percent U_{235}, assuming feed costs corresponding to the Nuexco Exchange and Conversion Values determined as of the same date.
6. In calculating the Transaction Value, Nuexco does not account for the price of uranium delivered in connection with contracts which call for "market price" mechanisms. This exclusion applies particularly to contracts in which delivery prices are expressed as a function of future Exchange Values or any other indeterminate variable. Also excluded from the calculation are any other transactions in which the delivery price is defined in such a way that it cannot currently be determined.

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CURRENT MARKET DATA

EXCHANGE VALUE EXPRESSED IN SELECTED PRODUCER & CONSUMER CURRENCIES[1]

Country (currency)	per lb. U_3O_8 in Concentrates			per kg. U in Concentrates		
	This Month (Nov 30, 1986)	Last Month (Oct 31, 1986)	12 Months Ago (Nov 30, 1985)	This Month (Nov 30, 1986)	Last Month (Oct 31, 1986)	12 Months Ago (Nov 30, 1985)
Australia (dollar)	25.85	26.46	24.31	67.20	68.79	63.20
Belgium (comm. franc)	694.16	724.95	861.18	1,805	1,885	2,239
Canada (dollar)	23.22	23.61	23.08	60.36	61.38	60.01
EEC (ecu)	16.16	16.46	19.33	42.02	42.80	50.27
Finland (markka)	82.31	84.75	91.63	213.99	220.32	238.22
France (franc)	108.98	113.86	129.85	283.32	296.02	337.57
FRG (mark)	33.27	34.85	42.62	86.50	90.60	110.80
Italy (lira)	23,116	24,107	28,741	60,097	62,672	74,719
Japan (yen)	2,715	2,742	3,368	7,059	7,128	8,755
Netherlands (guilder)	37.86	39.43	47.82	98.43	102.52	124.31
South Africa (rand)	37.64	38.64	44.14	97.86	100.45	114.75
Spain (peseta)	2,254	2,334	2,625	5,859	6,068	6,825
Sweden (krona)	115.68	119.13	128.55	300.73	309.71	334.20
Switzerland (franc)	27.69	28.90	35.06	71.98	75.14	91.14
UK (pound)	11.75	12.12	11.41	30.55	31.51	29.66
US (dollar)	16.75	17.00	16.75	43.55	44.20	43.55

TRANSACTION VALUE EXPRESSED IN SELECTED PRODUCER & CONSUMER CURRENCIES[1]

Country (currency)	per lb. U_3O_8 in Concentrates			per kg. U in Concentrates		
	This Month (Nov 30, 1986)	Last Month (Oct 31, 1986)	12 Months Ago (Nov 30, 1985)	This Month (Nov 30, 1986)	Last Month (Oct 31, 1986)	12 Months Ago (Nov 30, 1985)
Australia (dollar)	26.70	26.85	22.93	69.41	69.80	59.62
Belgium (comm. franc)	716.95	735.61	812.34	1,864	1,912	2,112
Canada (dollar)	23.98	23.96	21.77	62.34	62.28	56.60
EEC (ecu)	16.69	16.75	18.24	43.40	43.56	47.42
Finland (markka)	85.01	85.99	86.43	221.01	223.56	224.71
France (franc)	112.56	115.54	122.48	292.62	300.38	318.42
FRG (mark)	34.37	35.36	40.20	89.34	91.94	104.52
Italy (lira)	23,875	24,461	27,110	62,070	63,594	70,481
Japan (yen)	2,804	2,782	3,177	7,291	7,233	8,258
Netherlands (guilder)	39.10	40.01	45.10	101.66	104.03	117.26
South Africa (rand)	38.88	39.20	41.63	101.07	101.92	108.24
Spain (peseta)	2,328	2,369	2,476	6,052	6,158	6,438
Sweden (krona)	119.48	120.88	121.26	310.61	311.72	315.25
Switzerland (franc)	28.60	29.33	33.07	74.34	76.24	85.97
UK (pound)	12.14	12.30	10.76	31.55	31.97	27.98
US (dollar)	17.30	17.25	15.80	44.98	44.85	41.08

[1]Calculated using currency exchange rates published in the *Wall Street Journal* on Nov. 26, 1986.

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CONVERSION VALUE EXPRESSED IN SELECTED PRODUCER & CONSUMER CURRENCIES[1]

Country (currency)	per lb. U as UF_6			per kg. U as UF_6		
	This Month (Nov 30, 1986)	Last Month (Oct 31, 1986)	12 Months Ago (Nov 30, 1985)	This Month (Nov 30, 1986)	Last Month (Oct 31, 1986)	12 Months Ago (Nov 30, 1985)
Australia (dollar)	2.78	2.96	2.32	6.12	6.52	5.12
Belgium (comm. franc)	74.60	81.02	82.26	164.46	178.63	181.36
Canada (dollar)	2.49	2.64	2.20	5.50	5.82	4.86
EEC (ecu)	1.74	1.84	1.85	3.83	4.78	4.80
Finland (markka)	8.85	9.47	8.75	19.50	20.88	19.30
France (franc)	11.71	12.73	12.40	25.82	28.06	27.34
FRG (mark)	3.58	3.90	4.07	7.88	8.59	8.98
Italy (lira)	2,484	2,694	2,745	5,477	5,940	6,052
Japan (yen)	291.78	306.45	321.67	643.27	675.61	709.17
Netherlands (guilder)	4.07	4.41	4.57	8.97	9.72	10.07
South Africa (rand)	4.04	4.32	4.22	8.92	9.52	9.29
Spain (peseta)	242.20	260.88	250.78	533.95	575.14	552.88
Sweden (krona)	12.43	13.31	12.28	27.41	29.35	27.07
Switzerland (franc)	2.98	3.23	3.35	6.56	7.12	7.38
UK (pound)	1.26	1.35	1.09	2.78	2.99	2.40
US (dollar)	1.80	1.90	1.60	3.97	4.19	3.53

SWU VALUE AND UF_6 VALUE EXPRESSED IN SELECTED PRODUCER & CONSUMER CURRENCIES[1]

Country (currency)	SWU Value delivery within one year (Nov 30, 1986)	UF_6 Value per kg.U in UF_6 This Month (Nov 30, 1986)	UF_6 Value per kg.U in UF_6 Last Month (Oct 31, 1986)
Australia (dollar)	123.46	74.07	74.71
Belgium (comm. franc)	3,315	1,989	2,047
Canada (dollar)	110.88	66.53	66.66
EEC (ecu)	77.19	46.32	46.48
Finland (markka)	393.12	235.87	239.28
France (franc)	520.49	312.30	321.50
FRG (mark)	158.92	95.35	98.40
Italy (lira)	110,406	66,243	68,066
Japan (yen)	12,968	7,781	7,742
Netherlands (guilder)	180.83	108.50	111.34
South Africa (rand)	179.78	107.87	109.09
Spain (peseta)	10,764	6,459	6,591
Sweden (krona)	552.49	331.49	336.37
Switzerland (franc)	132.23	79.34	81.60
UK (pound)	56.12	33.67	34.22
US (dollar)	80.00	48.00	48.00

[1]Calculated using currency exchange rates published in the *Wall Street Journal* on Nov. 26, 1986.

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CURRENT MARKET DATA

RECENT TRANSACTIONS[1]

Uranium Sales

Nuexco Transaction Number	Delivery Period	Approximate Quantity (thousands of pounds, U_3O_8 equivalent)	Approximate Price as Percent of Current Exchange or UF_6 Value	Seller	Buyer	Remarks
3876	1987	101-300	100	Producer	Trader	UF_6
3874	1987	101-300	100	Producer	Utility	
3865	1987	101-300	less than 103	R[5]	Trader	UF_6
3864	1986	less than 50	102	Trader	Trader	UF_6
3863	1989-1998	5,001-10,000	R[5]	Producer	Utility	
3862	1986	101-300	105	Producer	Utility	UF_6

Conversion Services
Secondary Market Sales

Nuexco Transaction Number	Delivery Period	Approximate Quantity (thousands of pounds, U equivalent)	Approximate Price as Percent of Current C.V.	Seller	Buyer	Remarks
3875	1987	300-600	94-100	Trader	Utility	

Enrichment Services
Secondary Market Sales

Nuexco Transaction Number	Delivery Period	Approximate Quantity[2] (thousands of SWUs)	Approximate Price[3] as Percent of Current SWU Value[4]	Seller	Buyer	SWU Origin	Remarks
3879	1986	less than 50	106	Trader	Utility	DOE	
3878	1987	50-100	104	Trader	R[5]	DOE	
3877	1987	101-300	94-98	R[5]	Utility	Eurodif	

[1]Transactions listed are not limited to those in which Nuexco was involved, but also include others of which Nuexco is aware.
[2]If tails assay is unknown or unspecified, Nuexco's calculation of SWU quantity assumes 0.20 w/o tails assay.
[3]Price is not normalized to 0.20% tails assay.
[4]Refers to SWU Value that corresponds to SWUs included in transaction. When prices and SWU values are expressed as discounts (e.g., X dollars less than DOE's USEC base price at time of delivery), the percentage refers to the ratio of the *discounts*, not the ratio of the prices.
[5]The notation *R* means that Nuexco either does not know, or that Nuexco has restricted that information to protect client confidentiality.

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URANIUM SUPPLY
(November 30, 1986)

Nuexco Project Number	Delivery Period[1] (Thousands of Pounds U_3O_8) Spot or Near-term[2]	Intermediate or Long-term	Remarks
Available for Sale:			
ACTIVE			
2335	400	—	
2740	100	—	
2764	260	—	UF_6
2777	500	—	
2880*	125	—	
2885B*	230	—	UF_6
2893A*	480	—	UF_6
2933	300	300 per year	1988-90
2967	200	—	
2973	15	—	
2975*	250	—	
2989	40	—	
2990*	130	—	UF_6
3023	500	500	UF_6
3121	500	—	
3129	500	500	
2263	—	400 per year	1988 on
2625	—	500 per year	1988 on
2781	—	250 per year	1988-95
2927	—	220 per year	1988-90
2981	—	600 per year	1988-91
TOTAL:	4,530		
INACTIVE			
2297	200	200 per year	1988-89
2336	250	250 per year	1988-94
2389	75	75 per year	1988-90
3128*	100	—	
TOTAL:	625		

*New or revised since last month.
[1] Measured from the date of this Report.
[2] For delivery within one year. This category excludes material deliverable within one year under other than spot or near-term contracts.
Projects removed since last month: none.

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CURRENT MARKET DATA

URANIUM DEMAND
(November 30, 1986)

Nuexco Project Number	Delivery Period[1] (Thousands of Pounds U_3O_8) Spot or Near-term[2]	Intermediate or Long-term	Remarks
Inquiries to Purchase:			
ACTIVE			
2956	350	350	U_3O_8 or UF_6
2977*	105	—	UF_6
2984*	145	—	UF_6
2991*	105	—	UF_6
3075*	65	—	
2738	—	1,000	1989 on
2962	—	500	1989 on
2985*	—	675 per year	1992 on
3019	—	200 per year	1988-91
3097*	—	300 per year	1988 on
TOTAL:	770		
INACTIVE			
2760	750	750 per year	1988-90
2798	70	—	
2948*	100	—	UF_6
2936	—	400 per year	1988-95
TOTAL:	920		

*New or revised since last month

[1]Measured from the date of this Report.

[2]For delivery within one year. This category excludes material deliverable within one year under other than spot or near-term contracts.

Projects removed since last month: 2681, 2739, 2893B, 2954.

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LOAN SUPPLY AND DEMAND
(November 30, 1986)

Nuexco Project Number	Delivery Period[1] (Thousands of Pounds U_3O_8) Within 1 Year	Beyond 1 Year	Remarks
Available for Loan:			
INACTIVE			
1938	2,000	—	UF_6
2036	500	—	
2667	800	—	
2920	2,000	—	
TOTAL:	5,300		

*New or revised since last month.
[1]Measured from the date of this Report.
Projects removed since last month: None.

No inquiries to borrow are reported this month.

CONVERSION SUPPLY AND DEMAND
(November 30, 1986)

Nuexco Project Number	Delivery Period[1] (Thousands of Pounds U as UF_6) Within 3 Years	Beyond 3 Years	Remarks
Available for Sale:			
ACTIVE			
2859	750	750	
2935	500	—	
2988	165	—	
TOTAL:	1,415		
Inquiries to Purchase:			
ACTIVE			
2833	400	—	
2949	250	—	
TOTAL:	650		

*New or revised since last month.
[1]Measured from the date of this Report.
Projects removed since last month: 2849.

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CURRENT MARKET DATA

SWU SUPPLY AND DEMAND
(November 30, 1986)

Nuexco Project Number	Delivery Period[1] (Thousands of SWUs) Spot or Near-term[2]	Intermediate or Long-term	Remarks
Available for Sale:			
ACTIVE			
2571	—	55	1987
2855	250	—	
3156*	70	—	1987
TOTAL:	320		
Inquiries to Purchase:			
ACTIVE			
2987*	100	—	1987-88
3015*	40	—	
TOTAL:	140		
Inquiries to Purchase:			
INACTIVE			
2878	60	—	
2879	250	—	
2999*	150	—	
TOTAL:	460		

*New or revised since last month.
[1]Measured from the date of this Report.
[2]For delivery within one year. This category excludes SWUs deliverable within one year under other than spot or near-term contracts.
Projects removed since last month: 2854, 2957, 2968.

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AUSTRALIA'S SUPPLY POSITION

Introduction

Events both within and outside of Australia are moving that country back into the forefront of uranium supply nations. During the mid and late 1970s, Australia's uranium was viewed as essential to help supply the requirements of then-anticipated future reactor programs. However, beginning around 1980, the combination of massive reactor cancellations worldwide and Australia's vacillating uranium policy resulted in many end-users perceiving Australia as an interesting *alternative* source of uranium supply rather than as a primary source. However, a number of recent developments indicate that a further shift is evident, and Australia may again be emerging as a key supplier nation.

1. An aggressive marketing campaign initiated by Energy Resources of Australia (ERA) in the USA has resulted in at least nine long-term contracts.

2. A pragmatic decision by the Australian government to end its embargo against France has allowed Queensland Mines Ltd. (QML) to resume uranium deliveries to Electricite de France.

3. Joint venture partners Western Mining and BP Australia decided to proceed with the Olympic Dam project, and recently won government approval of a sales agreement with the Swedish State Power Board.

4. Increasing political problems associated with uranium supply from South Africa and Namibia have resulted in pressures for new sources of supply.

5. A general belief exists among buyers that competitive situations should be enhanced, both between supplier nations and within those nations. Thus, as Southern Africa's role in world supply diminishes, Australia's importance in counterbalancing Canada has increased, as has Olympic Dam's importance in counterbalancing ERA.

Australian Producers —

Energy Resources of Australia (ERA)

ERA continues to produce uranium from its Ranger mine and mill at Jabiru at the rate of about 6.6 million pounds U_3O_8 annually, and has announced plans to double that capacity in two stages by the early 1990s. About 75 percent of current production is committed to shareholder customers in Japan, the Federal Republic of Germany and Sweden, and the balance is sold to Korean, Belgian and US utilities. Of particular interest are the US contracts, which now reportedly total nine and include American Electric Power, Florida Power & Light, Pennsylvania Power & Light, Philadelphia Electric, Portland General Electric, South Carolina Electric & Gas, Southern California Edison, Virginia Electric Power, and Wisconsin Electric Power.

While individual contract details are not available, aggregate deliveries under these contracts could total 2.5 million pounds U_3O_8 annually by the late 1980s or early 1990s. However, those contracts contain considerable flexibility, and the quantities actually delivered will be a function of contract price. In view of Australia's established floor price policy and the reluctance of US buyers to pay in excess of spot-market prices, it is apparent that these contracts with US buyers must contain not only incentives but also comprehensive price protection. Incentives include flexibility with respect to the quantity and timing of deliveries, as well as delivery price provisions that call for substantial discounts from the spot price whenever it exceeds the floor price.

To avoid being locked into long-term obligations to take and pay for uranium at prices in excess of the spot-market price, there are price or quantity related triggers that provide for the reduction, suspension, or termination of deliveries. The contracts also contain so-called debit/credit arrangements, under which amounts paid in excess of spot-market price are utilized to reduce future delivery prices that exceed the floor price. Some contracts have provisions that excuse the buyer from purchasing if the uranium cannot be utilized due to US import restrictions, unless the seller elects (or is required) to provide acceptable uranium through open-market purchases.

Under the ERA strategy, risks to both buyer and seller appear to be minimal, and the benefits could be substantial. Most importantly, ERA has been able to penetrate the US market, and every ERA customer is one less potential customer for Olympic Dam; few if any US utilities will buy significant quantities from more than one Australian supplier. Finally, US utilities risk little to become associated with a producer capable of providing supply for the life of the reactor.

If near-term uranium prices reach or exceed the Australian floor price, ERA will produce and deliver the uranium, assuring its market position. Subsequently, its next expansion of production capacity (to 9.9 million pounds U_3O_8 annually) would be base loaded. This would also be the case if the government alters or removes the floor price, even if prices do *not* rise. In the last scenario, if prices do not rise and the current floor price remains in effect, US buyers will likely reduce deliveries or opt out of the contracts with minimum financial exposure, and buy from other, more competitive sources. Presumably, ERA would be no worse off than if it had never entered into the contracts with US buyers.

The situation with ERA's other customers, particularly its shareholders, is more complex. From the onset of their deliveries, those customers have been contractually bound to take large tonnages at prices which were not only considerably higher than spot market levels but also higher than prices prevailing

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under long-term contracts covered by negotiated pricing terms. Notwithstanding the profits those other customers have earned as equity investors, their general unhappiness with the current arrangement is well known and there have been reports of negotiations toward a resolution of these difficulties.

Olympic Dam

The Olympic Dam (Roxby Downs) project was examined in detail in Report 218 (October 1986). Since then, the joint venture partners Western Mining and BP Australia have announced that the anticipated contract with the Swedish State Power Board has been approved by the Australian government. The transaction involves about 550,000 pounds U_3O_8 annually for the years 1989 to 1999. A contract with the United Kingdom's Central Electricity Generating Board is also reportedly close to completion.

Olympic Dam's marketing challenge is significant. Its primary Australian competitor, ERA, has been in production for some years and has established itself as a reliable supplier. Without a reversal of government policy, price competition is not a realistic strategy. Olympic Dam's thrust has been to present itself as a viable alternative to ERA, emphasizing flexibility and customer service. Assuming some buyers will prefer to have sellers in competition with one another, it appears that Olympic Dam should achieve a significant market share.

Queensland Mines

Queensland Mines is in a unique position, as it is the smallest of the current Australian producers and is the lowest-cost producer in Australia, if not the world. Its uranium is completely stockpiled, leaving only a milling operation at Nabarlek. Thus, QML possesses the lowest risk and highest security of supply. Current supply contracts exist with two Japanese utilities, one Finnish utility, and Electricite de France.

Lacking agreement with the Northern Land Council to explore for new deposits in the Northern Territory, QML is not in position to offer long-term supply, and accordingly finds itself at a considerable marketing disadvantage to ERA and Olympic Dam. With little uncommitted supply at present, QML is essentially a spot seller in a country where the government-mandated minimum price is nearly twice the current spot level. QML has stated that it is committed to the uranium business and continues to work towards obtaining authorization to resume its exploration activities in promising areas of Arnhem Land.

Politics and Policy

For many years, the uranium issue has been an integral part of the political situation in Australia and a contentious issue between political parties, within the Labor party itself, between Australian states, or even between the individual uranium companies. In general, the following observations can be made.

1. The Liberal and National Country parties have consistently adopted pro-uranium platforms.

2. The Labor party had been consistently anti-uranium when out of power. Since attaining power, economic reality has caused the Labor party leadership to adopt a policy of grudging acceptance. Nevertheless, a vocal left wing of the party remains categorically opposed.

3. Opposition to uranium mining is centered in the two most populous states, New South Wales and Victoria, which are also the main centers of union activity.

4. Official federal and state government policies and attitudes on uranium change when the party in power changes.

5. For a variety of reasons unique to Australia, uranium mining and export continue to be emotional issues with the Australian public.

6. The former government's policy of sequential development, and the current Labor government's current policy of limited development, have frequently set the various mining companies in opposition to one another as they maneuver for position.

Conclusion

Government and commercial rhetoric aside, Australia's hopes for gaining and maintaining credibility as a reliable, world-class supplier in the long term are dependent on two related factors. First, there must be confidence among buyers that successive Australian governments will not continue to change the policies concerning Australia's uranium supply. The current Labor government has taken steps in this direction by allowing Olympic Dam to proceed and by allowing the resumption of QML's deliveries to EdF.

Second, the government must adopt a realistic view of its ability to dictate commercial conditions. In the late 1970s, Australia squandered its opportunity to join the front rank of supplier nations. Today, the floor price is perhaps the primary example of a policy that directly contradicts economic reality. In the longer term, Australia will not be able to command prices substantially above those offered by other sellers. Much of Australia's marketing success was achieved in a different market environment or is a reflection of buyers seeking to balance geopolitically their sources of supply. Premium prices that were justifiable to initiate a project are not likely to remain justifiable in the long term.

The history of the floor price demonstrates that while even the most intransigent entities can change, that change is typically so slow that the opportunity motivating the change is lost. Initially, the floor price was established as US$30.00 per pound U_3O_8, at least 55 percent of which was subject to adjustment by certain Australian indices from January 1, 1980. That floor was escalat-

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ing as spot prices were falling, and by September 1980, the spot price was below US$30.00 and still declining. At that point, Australian sellers (presumably with government sanction) spoke of freezing the floor price at its then-current level until spot prices once again were higher than the floor price, at which time the floor would again be escalated.

As spot prices moved still lower, debit/credit arrangements began to appear in contracts, as did the first provisions for the reduction or suspension of deliveries if certain conditions appeared. With the continued weakness in spot prices during 1984, 1985 and 1986, it became apparent that the Olympic Dam partners could have problems launching the project if the existing floor price policy was not changed. Though not officially announced, it is clear that the government will approve sales contracts with more flexible pricing provisions. The current goal appears to be that the average price over the life of the contract should at least equal the floor price. More recently, there have been rumors to the effect that even lower prices might be acceptable in special circumstances, such as in short-term contracts where the contract duration would presumably be too short for the expected future price increase to bring the average price up to $31.00.

If so, the government may soon be forced to accept prices for *current* deliveries that are below the established floor. Much of that pressure will likely come from ERA's shareholder customers. Under the terms of their original contracts, those shareholders have the option to terminate deliveries after 1990 if, after 1984, they are obliged to pay the floor price for two years in a row. It would be surprising if Australia, having gained a significant market position and with the prospect of improving that position, failed to acknowledge and accept this commercial reality.

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GERMANY'S THTR 300 AND THE HIGH-TEMPERATURE REACTOR PROGRAM

Introduction

The Thorium High-Temperature Reactor (THTR 300) in the Federal Republic of Germany reached its rated power of 300 MWe for the first time in late September 1986. The unit reached commercial operation in April 1986. This event marked an important step in high-temperature reactor (HTR) development worldwide. The FRG embarked on the research and development of this generation of nuclear power reactor design over 25 years ago. Other countries' experience with gas-cooled reactors, most notably in the United Kingdom, was used in the development and construction of HTR plants in the FRG. The gas-cooled THTR 300 prototype plant, designed and built by consortia of manufacturing, construction, and nuclear fuel cycle companies, represents the second phase of the German HTR strategy. The companies involved in the commercialization of the HTR hope to apply the reactor line to electricity generation, process heat production, and they anticipate that HTR development will result in increased flexibility in the nuclear fuel cycle.

History of the HTR Program

Nuclear power research and development efforts in the FRG in the 1960s led to experimentation with reactor systems and designs other than the conventional light-water reactor. Among the most promising technologies are the fast-breeder reactor, under development in several nations, and the gas-cooled reactor. Of the latter, the Magnox line and the second-generation Advanced Gas-cooled Reactor (AGR) have been the foundation of nuclear power in the United Kingdom for decades. General Atomic (now GA Technologies Corporation) pioneered the high-temperature gas-cooled reactor in the USA, notably Public Service Company of Colorado's Fort St. Vrain plant. In the FRG, the high-temperature gas-cooled reactor was developed in the 1960s by Brown Boveri/Krupp Reaktorbau GmbH, now known as Hochtemperatur-Reaktorbau GmbH (HRB).

HRB built the first experimental high-temperature reactor, designated AVR-15, a 15-MWe unit located near Jülich. The unit, which began operation in 1967, utilizes a loose bed of spherical fuel elements which form the reactor core. During operation, the fuel elements are continuously added from above the core and discharged from below it, making plant shutdown for refueling unnecessary. The pebble bed core of the AVR-15 is cooled by a flow of helium gas, which is heated to between 700 and 950°C., depending upon the application. The heated gas flows through heat exchangers and is then recirculated through the core for reheating.

Shortly after operation of the experimental unit began, HRB and the research facility at Jülich, with financial support from Euratom and the federal government of the FRG, developed the design and plans for a 300-MWe Thorium High-Temperature Reactor (THTR). Interest on the part of a group of German electric utilities led to the formation of Hochtemperatur-Kernkraftwerk Gesellschaft mbH (HKG). Table 1 lists the participants and their respective ownership shares in HKG. HKG and Vereinigte Elektrizitaetswerke Westfalen AG (VEW) own the THTR project, and HKG oversees the construction and financing of it. HKG selected the site for the THTR in VEW's utility area, near the towns Hamm and Uentrop in North-Rhine Westphalia. In 1970, HKG placed the order for the plant's construction with a consortium composed of Brown, Boveri & Cie. AG, HRB, and Nukem GmbH.

Table 1

OWNERSHIP OF HKG[1]

Owner	Location (City)	Percent Share
VEW[2]	Dortmund	26
GKW[3]	Veltheim	26
Elektromark[4]	Hagen	26
GWH[5]	Hattingen	12
Stadtwerke Aachen AG	Aachen	5
Stadtwerke Bremen AG	Bremen	5
		100

[1]HKG = Hochtemperatur-Kernkraftwerk GmbH.
[2]VEW = Vereinigte Elektrizitaetswerke Westfalen AG.
[3]GKW = Gemeinschaftskraftwerk Weser GmbH.
[4]Elektromark, Kommunales Elektrizitaetswerk Mark AG.
[5]GWH = Gemeinschaftskraftwerk Hattingen GmbH.

Description of the THTR

Figure 1 shows a basic diagram of the plant. The THTR consists of a two-cycle system. In the primary circuit, heat generated in the core is transferred by the flow of helium gas primary coolant to the steam generator. The secondary circuit absorbs the heat to produce steam, which drives the turbine generators and is recycled. As in a pressurized water reactor, there is a distinct separation between the radioactive primary circuit and the non-radioactive secondary loop.

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The core consists of a statistically arranged bed of 675,000 spherical elements (Figure 2). Of those, about 358,000 are uranium-thorium fuel elements, about 44,000 are absorber elements, and about 273,000 are graphite moderator elements. The absorber and moderator spheres present in the initial core are gradually replaced by fuel elements in the first four years of operation. Each element is about the size of a tennis ball, and fuel elements contain 192 grams of carbon, 0.96 g uranium 235 (from 93-percent enriched uranium), and 10.2 g thorium 232. During neutron absorption, the thorium is converted into fissile U_{233}.

Each fuel sphere consists of a 5-mm-thick graphite shell surrounding a graphite matrix which contains coated fuel particles. The particles are UO_2 and ThO_2 kernels coated with three pyrocarbon layers, which serve to retain the fission products. This type of fuel element has two important advantages.

1. High mechanical strength due to the structural properties of the graphite shell and inner matrix;

2. The retention of fission products, so that little radioactive contamination is released to the circulating helium gas.

Figure 3 shows a cutaway view of the fuel spheres.

During operation, six coolant blowers force the helium coolant gas to flow downward through the reactor core. The fission heat raises the temperature of the helium to 770°C., and the gas is collected beneath the reactor core. From there it is directed to the steam generators. The helium gas transfers heat to water in the steam generators, where the helium is cooled to about 260°C., and is redirected to the core by the coolant blowers. Steam produced in the steam generators drives the turbine, is condensed in the condenser, and is pumped back to the steam generators.

The THTR employs a fuel circulating facility that permits the continuous loading and discharging of the spherical fuel, moderator, and absorber elements during operation of the plant. As in the AVR-15 experimental plant, the spheres are added from the top of the core and discharged from the bottom. The reactor core is divided into two refuelling zones, and each fuel element spends an average of six months in one passage through the core during full operation. After each passage through the core, each fuel element is tested in a burnup measurement vessel, and those that have not reached a specified degree of burnup are recirculated into certain areas of the core for further use. The placement of the used fuel spheres depends upon the distribution of power density.

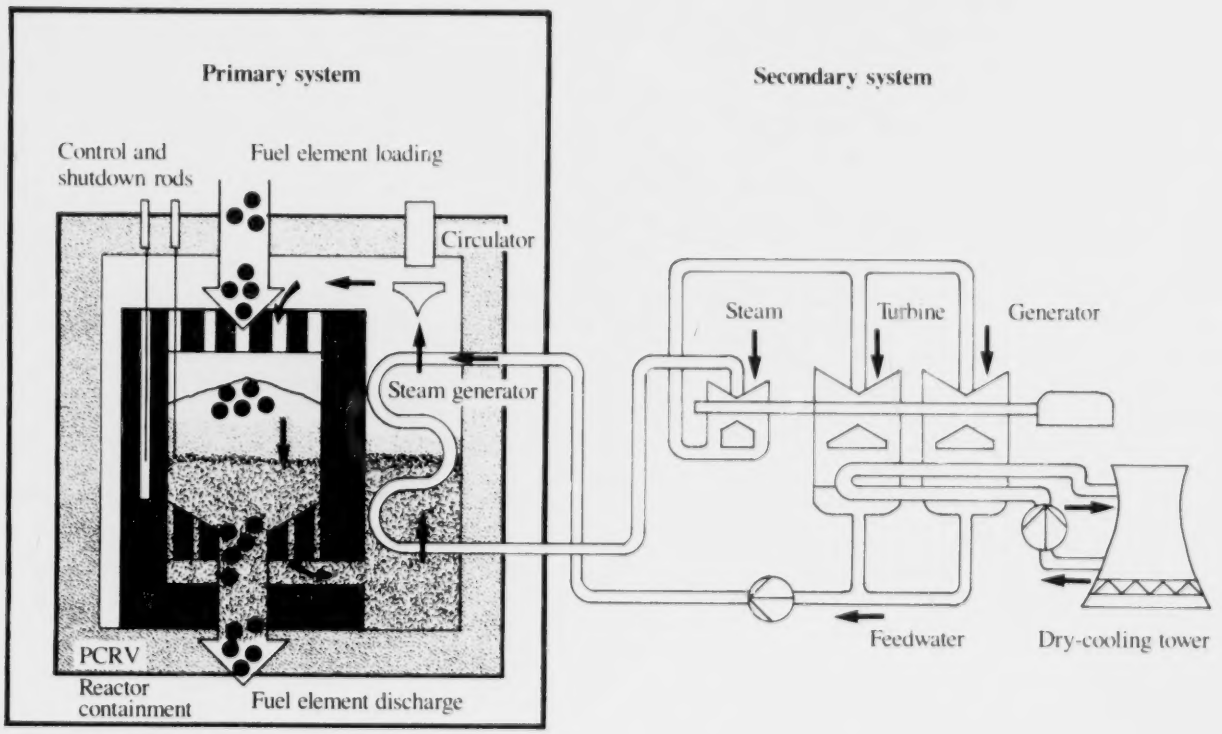

Figure 1. Basic diagram of the THTR-300.

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BASIC CONSIDERATIONS

Several features of the THTR were designed with particular attention to safety concerns.

1. The reactor core has a negative temperature coefficient, so that an increase in core temperature results in a decrease in reactivity. Neutron absorption by the thorium absorber in the fuel elements rises as temperature increases, reducing the core's reactivity.

2. The unit has a low ratio of power density to heat capacity, so that failures affecting heat production or removal (such as a loss of coolant accident) do not result in rapid temperature changes in the core.

3. The ceramic fuel elements have high temperature resistance and a high structural stability.

4. The core is equipped with two shutdown systems — a set of 36 absorber rods containing the absorber boron carbide (B_4C) inserted into the side reflector surrounding the pebble bed, and 42 in-core rods inserted directly into the bed. The side reflector rods are used to control pressure and temperature in the core, and the in-core rods are used for long-term shutdown. Both sets of rods would be inserted under accident conditions.

5. Helium's properties are ideal for a core coolant, because it is chemically inert and has no influence on reactivity. In addition, because it is a gas, a total loss of coolant cannot occur; at least one atmosphere of helium will remain inside the reactor vessel to provide decay heat removal.

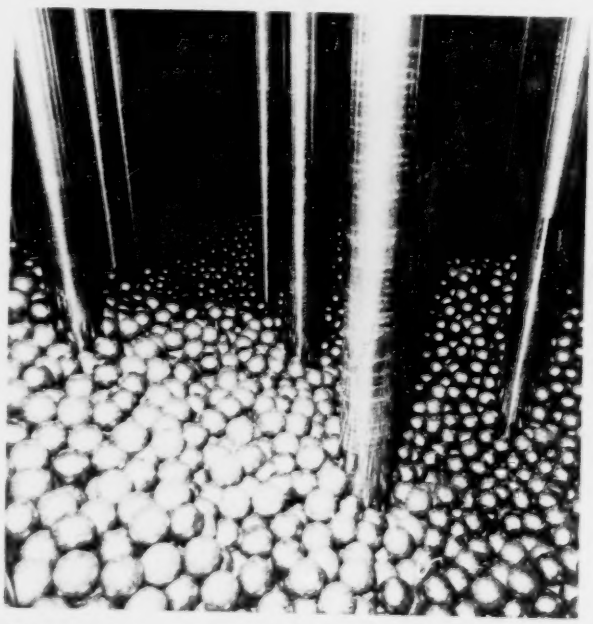

Figure 2. View of the reactor core, showing spherical fuel elements and in-core control rods.

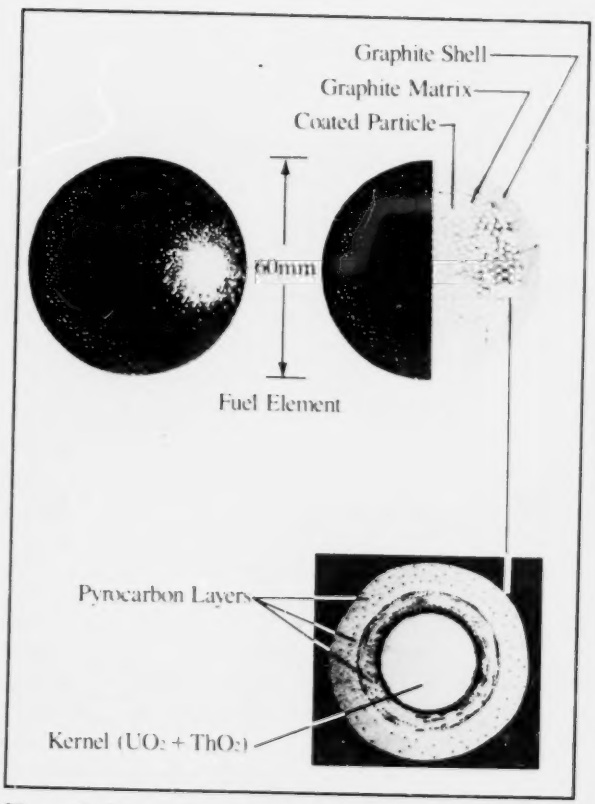

Figure 3. Structure of the THTR Fuel Element.

Commissioning of the THTR 300

Fuel elements were loaded in the THTR in August 1983. To avoid dropping the spheres from the full height of the core while it was empty, a special loading device was used. In October 1983, the core was fully loaded, and technicians withdrew the in-core absorber rods to achieve criticality so as to determine the effectiveness of the core design. Ten months later, a hot performance test was conducted utilizing nitrogen, which is a neutron absorber, in place of the helium coolant. Further testing during 1984 focused on reactivity measurements using nitrogen and helium, tests of the fuel circulating system, and control rod insertion tests. In April 1985, following the issuance of a second partial operating license, hot performance and safety systems tests began, using the helium gas coolant atmosphere at nearly operating pressures. Low-power nuclear operation began on September 6, 1985, and the unit was supplying electricity to the VEW grid shortly thereafter. HKG assumed ownership of the unit on April 11, 1986.

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Although the unit is in commercial operation, a condition of the operating license allows operation only until the core reaches its equilibrium burnup condition, which is expected to occur in three to four years. This condition is a result of political complications in the FRG over spent fuel storage sites. HKG has permission to store some spent fuel on the THTR site. However, court orders following regulatory disputes have closed the interim spent fuel storage site at Gorleben and have halted construction of a waste repository at Ahaus. As a result, HKG may encounter licensing problems if a longer-term spent fuel management solution is not found. Currently, reprocessing is not available for the THTR fuel spheres.

Future of HTR Program

The success of the THTR has already led to further development of the high-temperature reactor program in the FRG. Detailed design of a 550-MWe-plant, designated HTR-500, is underway, using technology and experience gained from operation of AVR-15 and THTR-300. Although the HTR program has been primarily promoted by the Ministry of Research and Technology branch of the federal government and the state of North-Rhine Westfalia, many utilities and nuclear fuel cycle companies are now initiating HTR research and development. The multiple potential applications of HTRs — for electricity generation as well as process heat utilization such as coal liquefaction and gasification — make the HTR an attractive design for future generations of nuclear power. Other areas of application include cogeneration of electricity and district heating, the production of synthetic gas from coal and other hydrocarbons, the production of methane or hydrogen from coal, and other potential uses. Some of these possible applications are part of an overall development plan by BBC/HRB, shown in Figure 4. The THTR will be the reference plant for the consortium's subsequent generations of high-temperature reactors.

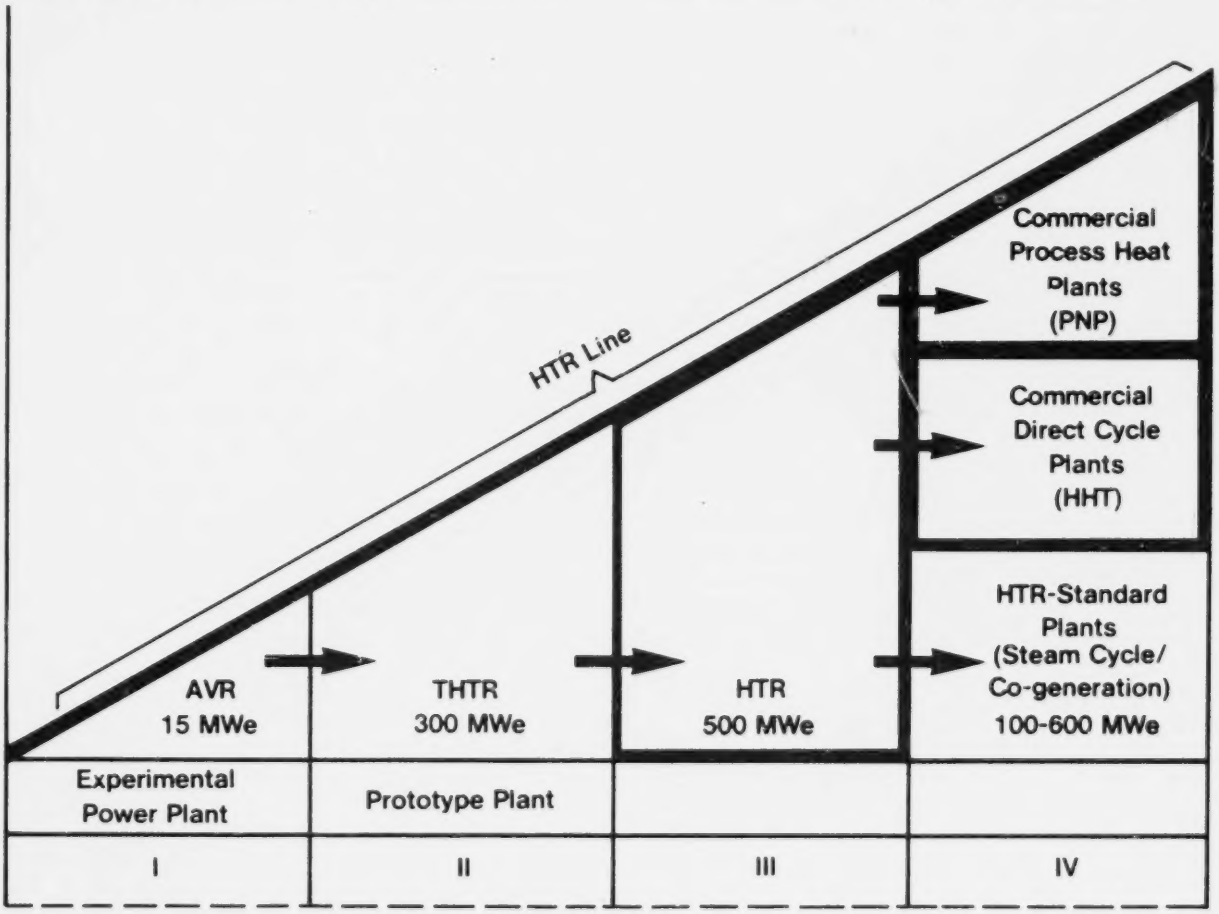

Figure 4. Sequence of Technical Development of the High-Temperature Reactor.

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RECENT DEVELOPMENTS

UNITED STATES

The US Energy Information Administration (EIA) has released its annual report entitled "Domestic Uranium Mining and Milling Industry: 1985 Viability Assessment." The EIA is an independent statistical and analytical agency within the US Department of Energy. A 1983 amendment to the Atomic Energy Act of 1954 requires the Secretary of Energy to make an annual determination of the industry's viability, and the EIA study is intended to provide the Secretary with the information needed to make such a determination. The 1985 assessment indicates that the condition of the US uranium industry is worse in most areas than it was in 1984, making a determination of nonviability almost a certainty. The Secretary of Energy has not yet issued his determination for 1985.

In his first annual determination for the calendar year 1983, the Secretary of Energy found that the domestic uranium mining and milling industry was viable, while noting concern with the long-term health of the industry. The following year, the Secretary determined that in 1984, the industry was not viable. As criticism of his findings increased, the Secretary announced that he would undertake three steps designed to bolster the domestic industry.

1. Herrington authorized DOE to offer a free variable tails assay option (VTAO) each year to all customers that commit to buy 100 percent of their requirements from DOE over a rolling five-year period.

2. He postponed for one year a DOE plan to feed some of its own uranium stockpile into enrichment plants. This item also was sought in Count IV of the US uranium producers' lawsuit against DOE. DOE subsequently told the Tenth District Court that it would not implement the plan at all.

3. He asked the US Trade Representative to examine the facts and implications of uranium imports and corresponding foreign trade and policy issues with a view toward determining the appropriate courses of action under US trade laws. Three months later, Trade Representative Clayton Yeutter recommended that no action be taken, citing the conclusions that any relief to the US industry from a standpoint of restricting imports would be at best only short-term relief, and would likely antagonize US trading partners.

Viability Assessment Criteria

Pursuant to a rulemaking in October 1983, the Secretary of Energy is required to monitor and make an annual determination of the viability of the US uranium industry. The rulemaking delineated several criteria that are to be considered in making the viability determination; the EIA study provides data and information that are fundamental measures of the industry's capability. Moreover, the study provides estimates of future capabilities under a variety of hypothetical conditions.

The criteria define four major "attributes of viability:"

1. *Resource Capability* — Whether domestic economic uranium reserves can supply all domestic needs for a future ten-year period.

2. *Supply Response Capability* — The level of domestic uranium production capacity sufficient to meet projected domestic nuclear power needs for a ten-year period.

3. *Financial Capability* — The ability of the domestic uranium industry to obtain funds adequate to finance the level of production capability defined under supply response capability.

4. *Import Commitment Dependency* — Whether executed contracts or options for (natural or enriched uranium) will result in greater than 37.5 percent of actual or projected domestic uranium requirements being supplied by (uranium) from foreign sources for any period of two consecutive years.

The EIA assessment provides current information and makes projections of future conditions of each of the four fundamental attributes as well as some related ones, such as a projection of industry status under both supply disruptions and free market conditions. Some of the most pertinent and interesting data and conclusions are summarized below.

Current Status of the Industry

The report concludes that almost all of the short-term indicators of the domestic uranium industry's health are weak, and many are weaker than in the previous assessment; that assessment resulted in the Secretary's finding that the industry was not viable for 1984. Some of the more important indicators are the following.

1. US uranium production in 1985, which totaled 11.3 million pounds U_3O_8, declined to its lowest level since 1956. The 1985 figure represented a 24-percent decline from 1984 production of 14.9 million pounds U_3O_8.

2. After realizing positive net income in the years 1981-1983, the US industry lost a total of $307 million in 1984. Total losses increased to $350 million in 1985.

3. The number of firms investing in domestic uranium exploration, mining and milling, as well as their associated capital investments, have reached their lowest levels since the government began collecting such statistics in 1973. Exploration expenditures fell from $27.4 million in 1984 to $20.1 million in 1985. Drilling activity, the primary indicator of exploration effort, fell from 2.5 million feet in 1984 to 1.8 million feet in 1985.

4. The production costs of the vast majority of US uranium

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producers are well above recent contract prices.

The 1985 status of import commitment dependency showed that the US utilities as a group relied a little less on imported uranium for their requirements than in previous years. Natural uranium imports represented 52 percent of US requirements in 1982, 25 percent in 1983, 39 percent in 1984, and 34 percent in 1985. However, this indicator will fluctuate widely from year to year depending on contract volume, and it is difficult to discern any real trends from these figures. It might be more valuable to examine these figures in relation to the volume of uranium purchased by US utilities. Moreover, the study concludes that foreign-origin uranium is "likely to fill a growing portion of currently unfilled utility requirements and long-term utility purchase commitments with domestic suppliers during the second half of this decade." In the 1990s, import dependency could range from 45 percent to as high as 60 percent of domestic utility requirements, according to the EIA report.

Import commitment dependency that results in imports totaling more than 37.5 percent of US requirements for two consecutive years is one of the criteria used to assess viability. However, that dependency indicator's fall to 34 percent in 1985 is not, in itself, sufficient for a finding of industry viability. Other factors and indicators, many of which declined further from last year's marks, will negate the effect of the small decline in import dependency.

Disruption Scenarios and Supply Response Capability

Hypothetical supply disruption scenarios are used to estimate the US industry's ability to respond over the next ten years to a one-third disruption of uranium import contracts now in place. In other words, if only two-thirds of the non-US uranium supply currently under contract were actually delivered, would the US production sector be able to fill any void left by the decline in imports of non-US uranium? To arrive at the estimates, the study examines the US industry's resource capability, financial capability, and ability to meet the supply security requirements of US utilities. The EIA study concluded the following:

1. Even with a one-third disruption of foreign supplies, domestic uranium suppliers report that US resources are sufficient to meet domestic uranium supply security requirements through 1996.

2. DOE estimates of reasonably assured resources in the USA support the above conclusion.

3. In the short term, the US uranium production sector would have the *technical* capability to meet domestic supply security requirements in the event of a one-third disruption. However, in the 1991-2000 period, the EIA report indicates that production capacity would fall short of requirements by five to eight million pounds U_3O_8 in the event of a hypothetical one-third import disruption.

4. For the short-term disruption scenarios, mining and milling capacity that already exists, either in operation or standby, can meet uranium requirements through reactivation and increased utilization. However, higher uranium prices would be required to increase production during a disruption period.

Conclusion

It is clear from the EIA viability assessment that it will be difficult for Energy Secretary Herrington to determine that the US uranium industry was viable during 1985. The industry's profitability, production levels, and future supply capability have all declined further. The finding of nonviability for 1984, therefore, will practically force Herrington to repeat that finding for 1985.

A second finding of nonviability will place added pressure on DOE to implement measures to bolster the US industry. But because DOE has avoided implementing any effective measures for several years, and has indicated that it intends to continue such a policy, the producers are not likely to receive any significant help from DOE even if the industry is found to be nonviable for the second consecutive year. At this stage, it appears that only a final ruling in favor of the US producers in their lawsuit against DOE will provide the industry with any real relief.

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RAW MATERIALS

SOLUTION MINING OF URANIUM, Part I

Introduction

Solution mining technology has improved steadily over the past ten years, a period of generally poor industry economics in which operating and regulatory costs have escalated considerably. In general, solution mining represents a cost-effective and environmentally attractive means to produce uranium, especially from the low-grade reserves often found in the USA. The emphasis on uranium production in the United States continues to shift from underground and open-pit mining and conventional milling procedures to solution mining techniques.

Overview of Solution Mining

Solution mining of uranium is commonly referred to as in-situ leach mining (ISL). The solution mining process, however, requires that the target ore be confined within an aquifer, and so it is considered an extension of in-situ leaching. Often the two terms are used interchangeably, and both use the principle of hydrometallurgy to recover metals from various ores. Technically, as practiced today, solution mining is limited to uranium recovery, while the application of ISL techniques also applies to the recovery of other metals. ISL refers to the induction of a special leach solution into any suitably prepared ore deposit. The desired mineral is leached from the deposit, enriching the solution before the solution is recaptured. The final steps of the hydrometallurgical process include mineral extraction (from the pregnant solution), concentration, and precipitation. In addition to uranium, other metals such as copper, gold, silver and manganese are amenable to varied ISL applications.

The recovery of uranium by solution mining is uniquely dependent upon the ore deposit and host formation being confined within an aquifer. The aquifer water serves four important functions in the leaching/recovery process:

1. It is used to form the leach solution;
2. It serves to move the leach solution within the deposit;
3. It allows operational control of the induced solution, particularly over possible solution excursions outside the desired area of influence;
4. The natural flow of the aquifer helps restore a natural state from chemical changes that may occur in the groundwater and host formation during the leaching process.

Containment of all leach solutions is normally achievable throughout the life of the project. The use of aquifer waters in the mining process, followed by aquifer restoration, represents the technological differences between solution mining and straight ISL mining.

Solution mining is derived from the more conventional techniques for mineral recovery by induced solutions, including heap leaching, in-place leaching and percolation leaching. The technology generally has been applied to the recovery of uranium in situations where ore concentrations and geologic conditions were poorly suited to conventional mining methods. Early research and development focused on using the hydraulic and chemical characteristics of the aquifer waters in a closed circuit of leaching and recovery, which the developers of the process referred to as solution mining. Since then, the technology has improved, but the basic concept remains the same.

Geological Requirements

Many sandstone uranium deposits located in the western USA have characteristics favorable to solution mining. However, virtually all solution mining activities to date have been limited to paleochannel sand units within Tertiary formations in Texas and Wyoming. Projects in other regions have been initiated, usually in older host rocks, but none have operated successfully; reasons for this lack of success have ranged from unfavorable geochemistry to unfavorable economics and politics.

Successful solution mining depends greatly upon orebody characteristics and selection of the most effective lixiviant (the solution used in the process). The ore minerals must have been deposited in a reducing environment (i.e., they must be in an oxidized state), and the ore deposit must be of sufficient size, shape and thickness to accommodate mining procedures and produce advantageous economic results. Roll-front deposits fit the requirements well, being long and sinuous and reasonably flat-lying. Although higher-grade ores naturally offer greater economic potential, the process was developed out of a need to mine low-grade ore. Considering this, a grade of 0.10 percent U_3O_8 is about average in past operations, although some projects have operated with lower grades. Projects presently under consideration for commercial start-up are supported by higher-grade deposits as a matter of economic necessity.

Roll-front deposits common to Tertiary channels are readily amenable to solution mining. Generally, these ore deposits are associated with poorly-sorted sands and conglomerates where consolidation is incomplete, and so permeability is usually favorable. Roll-type uranium deposits occur along a chemical front which clearly exhibits an oxidation/reduction zone. When the leach solution (lixiviant) comes into contact with insoluble uranium oxides and silicates, oxidation occurs and quadravalent (+4) uranium minerals (uraninite and coffinite) are converted to the hexavalent state (+6), forming soluble uranyl carbonates. In the recovery plant, the uranium dissolved in the lixiviant is

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concentrated by ion exchange methods followed by precipitation.

Adequate formation permeability is extremely important to the distribution and contact rate of lixiviant through the mineral zone. Successful solution mining requires permeabilities that allow rapid movement of aquifer fluids and induced lixiviants. Most Tertiary sandstone units exhibit relative high rates of permeability; the older and deeper sandstones, such as the uranium-bearing Jurassic formations of the Grants mineral belt in New Mexico, are well-compacted and show considerably less permeability. Many geologically older ore deposits may not be suitable for solution mining primarily for that reason.

Depth of the ore-bearing strata is directly related to mineability and project economics. As mentioned above, permeability is likely to be adversely affected by depth. In addition, exploration, development, and construction costs increase rapidly at increased depths, and operating costs will be higher because of increased pumping costs. On the favorable side, oxidation induced by contact with the lixiviant is more efficient because of greater formation pressure, potentially increasing the uranium recovery rate.

Another critical condition for successful mining concerns the characteristics of the confining aquifer. Confinement of all natural and induced fluids is controlled by the presence of impermeable formations above and below the ore-bearing strata. Such layers may consist of either shale, clay and mudstone, or any combination. The impermeable layers are necessary to contain the normal aquifer flow and to aid in the manual control of the lixiviant, both horizontally and vertically. In a suitable geologic setting, the potential for fluid excursions and contamination of other aquifers is greatly reduced.

The impermeable bottom layer is definitely required for solution containment; however, the upper confining layer could be absent under near-perfect conditions of formation thickness, permeability, hydrostatic equilibrium of groundwater, and positioning of the ore zone near the base of the aquifer. In such a case, project operations must be monitored closely to check for lixiviant movement upward into barren portions of the aquifer.

Geochemistry

Host rock mineralogy and groundwater chemistry must be understood in order to develop an efficient mining process. As a result of rapid changes in the sedimentary sequence, physical properties may vary greatly between fine to very coarse-grained sands and conglomerates. Each change represents a probable variation in host rock mineralogy. The presence of clay particles, especially in finer-grained materials, tends to reduce porosity and permeability, thus restricting mining efficiency. Pyrite grains and carbonaceous fragments commonly occur throughout much of the depositional sequence associated with uranium mineralization. Each is a known oxygen consumer and the presence of one or both requires a higher injection rate of the primary oxidant used in the operation, be it hydrogen peroxide or liquid oxygen, increasing operating costs accordingly. If pyrite is present, mild sulfuric acid is generated. The acid may cause the precipitation of gypsum, which will tend to decrease formation permeability as well as adversely affect upstream process equipment. In addition, the presence of vanadium or molybdenum can foul the recovery circuits.

Usually groundwater chemistry is relatively simple. If the chloride content is less than 2.5 grams per liter, and total dissolved solids are less than 10,000 ppm, the water is usable without much adjustment other than the addition of proper amounts of leaching chemicals. Information about the quantity of available water, its direction of flow, and the hydrostatic pressure must also be determined. If an adequate quantity of groundwater is not available and another source of water must be introduced, production costs will increase and restoration costs probably will increase.

During the exploration phase of the project, subsurface conditions are evaluated leading to a preliminary understanding of orebody characteristics. The design process begins with the first mineralized holes drilled. Characteristics of the aquifer are determined during the drilling phase, and confirmed through on-site testing. Chip and core samples taken from holes strategically placed over the ore deposit are carefully evaluated for all essential characteristics, including ore amenability to leaching. Development of a suitable lixiviant is started in the laboratory and finalized by actual on-site pilot testing. Engineering design work is followed by the application of state-of-the-art process technology for the leaching and recovery facilities.

Lixiviant Formulation

The rate of uranium dissolution in the presence of the selected lixiviant is the most critical chemical process of a solution mining operation. Especially during the early years, the determination of the right lixivant was done by trial and error. Today, however, it is a more precise science, subject to variation in each application. The chemical makeup of any lixiviant is initially based on the geochemistry of the ore deposit and is confirmed in the laboratory. Chemical formulation aims to achieve maximum uranium extraction with minimum changes to host rock permeability and aquifer chemistry. Two types of lixiviants are normally used — acid and alkaline — and each has advantages and disadvantages depending on process technology, location, and economics. One of the primary considerations in lixiviant selection is the need for both surface and subsurface restoration.

Sulfuric acid combined with an oxidant is an extremely

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efficient leaching agent for oxidized uranium, and has been used in solution mining operations with considerable success. Unfortunately, it will dissolve a variety of other minerals that can contaminate the uranium recovery system. Its reaction with clays, calcite, and quartz grains causes precipitation of gypsum and silica gel, both of which reduce formation permeability. Sulfuric acid is no longer acceptable for solution mining in the USA, primarily due to environmental concerns. Nitric acid has also been used, but is less effective and more costly than sulfuric acid.

Alkaline-based lixiviants are now used almost exclusively throughout the industry. In the early 1970s, ammonium carbonate-bicarbonate was used extensively. Leaching results were extremely favorable, but restoration of the groundwater and the removal of ammonia cations from clay minerals proved troublesome, resulting in a ban on its use. Sodium carbonates are now the most widely used lixiviants. Sodium carbonate has the advantage of leaching primarily uranium, but at a comparatively slow rate; many other minerals or chemicals remain unaffected. A high pH is easily maintained throughout the system, almost completely eliminating the precipitation of calcite which could decrease permeability. However, sodium may cause swelling in certain clays such as montmorillonite, which definitely reduces permeability. The use of sodium carbonate (or any carbonates) also improves restoration procedures. Potassium carbonate in particular has a high leach rate and is easily recovered, allowing for rapid restoration. It has not been used on a commercial scale because it is more expensive than other carbonates, but still has the potential for increased use due to its restoration qualities.

Oxidants must be added to the lixiviant to convert the uranium to the hexavalent state (+6). Currently the most favored oxidant is liquid oxygen. Since the development of down-hole techniques to introduce oxygen gas into the lixiviant stream at the point of injection, its use had become widely accepted by the late 1970s. Oxygen quickly proved more efficient and less costly than hydrogen peroxide, which was used extensively up to that time. Sodium chlorate and air also have been used as oxidants but with considerably less efficiency.

Restoration Procedures

Solution mining projects are allowed to begin commercial production under the condition that technology is provided for the satisfactory restoration of subsurface geochemical systems at the end of the mining cycle. The primary concern is the restoration of the aquifer and host rock. Specifications for subsurface restoration are based on generic regulatory standards and site-specific standards established after an extensive environmental baseline study, and may vary considerably from state to state. Jurisdiction over restoration procedures and regulatory compliance may originate from any combination of local, state and federal agencies, depending on the geographic location of the project.

Surface restoration requires returning the land to its original condition. This is usually not a difficult task, since the surface has not been disturbed by deep trenching or open-pit mining. Buildings, foundations, and process equipment, including well-field piping, obviously must be removed. Well casing, tubing, and pumps are completely removed from each drill hole and the hole is sealed to within a few feet of the surface. Liquid effluent left over from plant cleanup may be disposed of by natural evaporation or by injection into a deep disposal well designed and approved for that purpose. Pond liners (if any) and contaminated equipment, building material and yard dirt may be buried on-site or at a special disposal site approved by the regulatory agency. Restoration is concluded by reseeding all areas affected during the life of the project.

Restoration of the subsurface geochemical system is a more complicated and time-consuming operation, the object of which is to reduce the effects of leaching as much as is practical. Several techniques are available, depending upon the nature of the task. The most commonly used technique is to reverse the direction of most injection wells to maintain steady pumping of residual fluids out of the area encompassed within the well field. Normal groundwater flow will gradually replace the water pumped to the surface. By regulating the pumping sequence, a sweeping action can be developed which will eventually remove the last traces of lixiviant and its effect from the aquifer and the host rock. Continual laboratory testing is necessary to determine the point at which groundwater conditions have reached a normal state, or at least an environmentally acceptable state, before pumping can be terminated. Ideally, groundwater pumped to the surface is treated to remove undesirable chemicals and reinjected into the aquifer to hasten the restoration. Waste-stream materials concentrated by this process are disposed of by evaporation or deep well injection.

The injection of special fluids into the aquifer may be required under more severe conditions of contamination. If such contamination goes undetected, restoration problems and costs may become extreme. The special fluids, designed to correct and stabilize a chemical imbalance, will expedite recovery of lixiviant ions that may become attached to clay particles, or reduce the dissolving of particles unfavorable to the ISL recovery system. In this situation, it may be necessary to specially treat the returned fluids to remove contaminants. The processes of electrodialysis/ion exchange and reverse osmosis are the two most commonly used. The waste streams from such processes are permanently disposed of by evaporation or deep-well injection.

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Monitoring Program

Each solution mining project must have a monitoring program in place before commercial operations begin. The purpose of a monitoring program is to establish a record of natural environmental conditions before mining begins in order to estimate the potential impact the project may have on the local environment. In fact, the monitoring program is maintained throughout the life of the project and for an indefinite period afterward, depending upon the level of success attained in restoration. Every monitoring program is designed according to specifications contained in regulatory requirements. Regulations developed to maintain an environmental balance for the project area become an integral part of operational procedures.

Prior to mining, surface monitoring studies determine prevailing environmental conditions and the potential impact of surface construction and plant operation on air, soil, erosion by wind and water, fauna and flora, and surface water quality. Permanent sample stations are built for this purpose. Subsurface standards are established for control of groundwater quality. This is accomplished by drilling a pattern of wells into the aquifer containing the ore deposit. Wells are also drilled inside the ore deposit to determine water quality prior to mining. Restoration standards for the aquifer are established on this information. Water quality monitoring wells are also drilled around the outer limits of the area to be mined. These wells are placed to provide continual checking for excursions of lixiviant during the leaching phase. The number of monitoring wells drilled, and the sampling procedures used, are usually determined by the principal regulatory agency. The mine operator is obligated to maintain each monitor well and surface station, supported by formal written reports sent directly to the regulatory agency.

The mine operator is also required to establish a radiological monitoring program to take effect as mining begins. Determination of natural background levels for selected radionuclides, including, gross alpha/beta, radon-222, radium-226, thorium-230, and U_3O_8, is established as a guideline before mining begins. Sampling devices must be provided to monitor chemical and radiological contamination that may occur from the accidental release of atmospheric and liquid effluents in and around the plant site. Radioactivity and dust levels in all workplaces are monitored constantly. The object of this monitoring is to reestablish the natural background level of radionuclides during postmining restoration. Once restoration to pre-determined levels has been accomplished, monitoring continues for at least one year to verify success.

Conclusion

, Solution mining presents an increasingly attractive technique for mining some types of uranium ores commonly found in the USA. Although application of this method requires specific geological conditions to be successful, it is especially economical for extracting ores containing a low concentration of uranium. Given the economics of mining in today's market for uranium and the current environmental regulatory climate, solution mining can be expected to supply an increasing percentage of US uranium in the years to come. Part 2 of this article will address specific solution mining projects in the USA.

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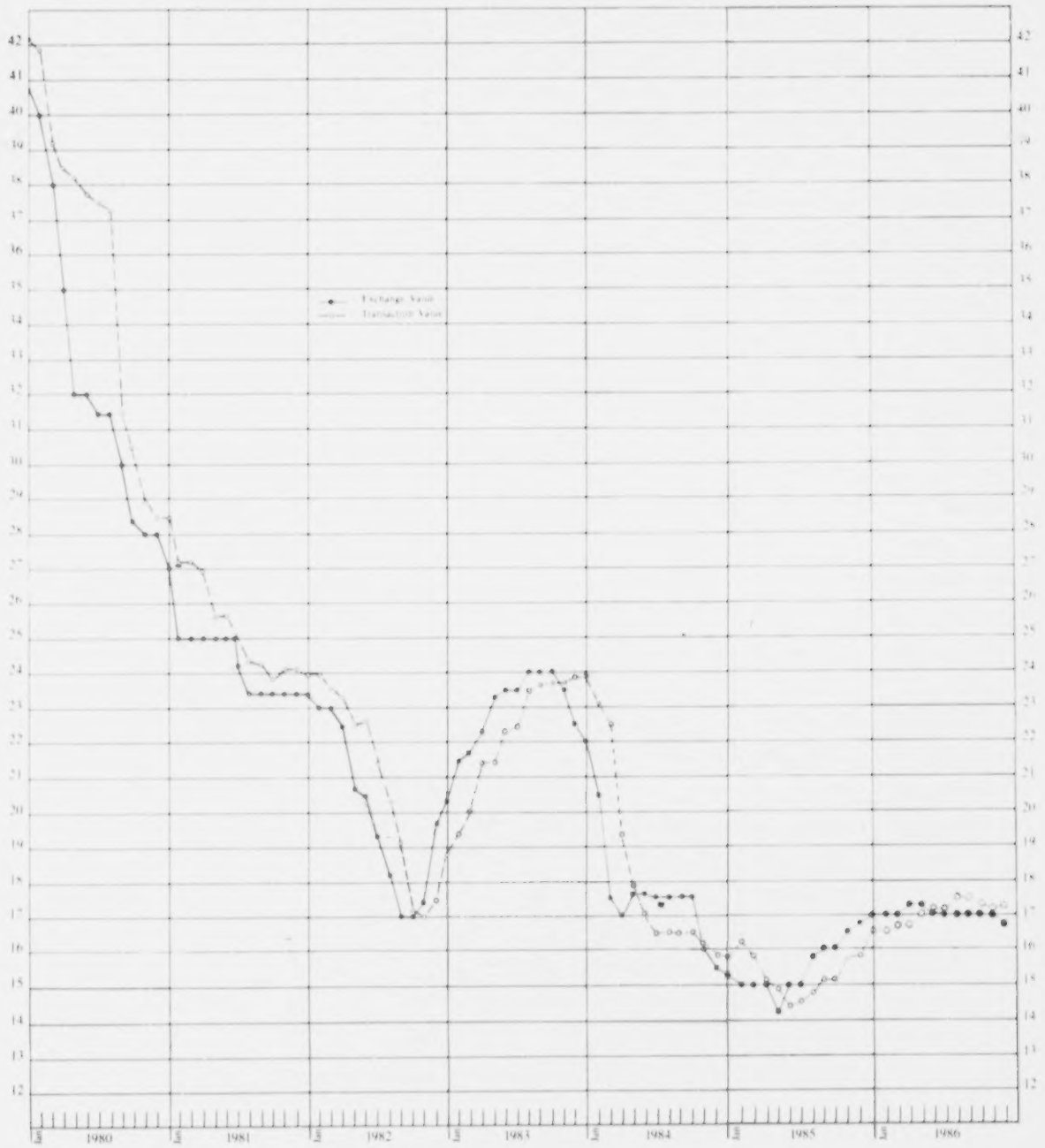
HISTORICAL MARKET DATA

EXCHANGE AND TRANSACTION VALUES
SINCE JANUARY 1980

Determined as of the last day of the month indicated



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HISTORICAL EXCHANGE VALUES

Determined as of the last day of the month indicated (US Dollars/lb. U_3O_8)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1968	—	—	—	—	—	—	—	6.35	6.35	6.40	6.45	6.50
1969	—	6.35	6.10	6.10	6.25	6.25	6.20	6.20	6.15	6.15	6.15	6.20
1970	6.30	6.30	6.30	6.30	6.30	6.30	6.30	6.20	6.15	6.15	6.15	6.15
1971	6.20	6.20	6.20	6.20	6.15	6.05	6.00	5.95	5.95	5.95	5.95	5.95
1972	5.95	5.95	5.95	5.95	5.95	5.95	5.95	5.95	5.95	5.95	5.95	5.95
1973	5.95	6.00	6.10	6.20	6.45	6.50	6.50	6.50	6.50	6.50	6.75	7.00
1974	7.70	7.90	8.00	9.00	9.50	10.50	11.50	12.00	12.50	14.00	14.75	15.00
1975	16.00	16.00	18.00	20.00	21.00	23.00	24.70	26.00	26.00	28.50	30.00	35.00
1976	35.20	37.00	39.25	40.00	40.00	40.00	40.00	40.40	41.00	41.00	41.50	41.00
1977	41.35	41.50	41.60	41.60	42.00	42.25	42.25	42.25	42.40	42.75	43.20	43.20
1978	42.90	43.25	43.25	43.25	43.40	43.40	43.40	43.10	43.25	43.00	43.25	43.25
1979	43.25	43.25	43.25	43.25	43.25	43.00	42.70	42.70	42.20	42.20	41.00	40.75
1980	40.00	38.00	35.00	32.00	32.00	31.50	31.50	30.00	28.50	28.00	28.00	27.00
1981	25.00	25.00	25.00	25.00	25.00	24.25	23.50	23.50	23.50	23.50	23.50	23.50
1982	23.00	23.00	22.50	20.75	20.50	19.25	18.25	17.00	17.00	17.50	19.75	20.25
1983	21.50	21.75	22.25	23.25	23.50	23.50	24.00	24.00	24.00	23.50	22.50	22.00
1984	20.50	17.50	17.00	17.75	17.75	17.50	17.50	17.50	17.50	16.00	15.50	15.25
1985	15.00	15.00	15.00	14.25	15.00	15.00	15.75	16.00	16.00	16.50	16.75	17.00
1986	17.00	17.00	17.25	17.25	17.00	17.00	17.00	17.00	17.00	17.00	**16.75**	

HISTORICAL TRANSACTION VALUES

Determined as of the last day of the month indicated (US Dollars/lb. U_3O_8)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1976	—	—	—	—	39.60	39.70	39.70	40.40	40.30	40.60	40.70	40.70
1977	41.30	41.30	41.40	41.50	42.80	42.90	43.00	42.60	42.50	42.80	42.90	42.90
1978	43.10	43.30	43.70	43.60	43.60	43.20	43.30	43.40	43.40	43.60	43.40	43.70
1979	43.60	43.80	43.70	43.40	43.60	43.70	43.70	43.60	43.60	43.60	43.50	42.30
1980	42.00	39.30	38.60	38.40	37.90	37.60	37.30	31.60	30.60	29.00	28.70	27.70
1981	27.20	27.20	27.00	25.70	25.70	24.50	24.40	24.30	23.90	24.10	24.10	24.00
1982	24.00	23.70	23.40	22.60	22.70	21.50	20.30	19.10	17.30	17.00	17.55	18.80
1983	19.35	20.00	21.35	21.40	22.35	22.45	23.50	23.60	23.65	23.65	23.85	23.85
1984	23.05	22.50	19.25	17.90	17.00	16.50	16.60	16.40	16.55	16.05	15.90	15.90
1985	16.20	15.70	15.05	14.90	14.45	14.60	14.75	15.10	15.10	15.75	15.80	16.55
1986	16.55	16.70	16.70	17.10	17.15	17.20	17.50	17.45	17.35	17.25	**17.30**	

HISTORICAL CONVERSION VALUES

Determined as of the last day of the month indicated (US Dollars/lb. U in UF_6)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1981	1.20	1.20	1.20	1.40	1.15	1.15	1.15	1.10	1.10	1.10	1.20	1.20
1982	1.20	1.20	1.20	1.20	1.00	1.00	1.00	0.90	1.10	1.60	1.45	1.45
1983	1.20	1.40	1.40	1.20	1.20	1.20	1.10	1.10	1.00	0.60	0.60	0.60
1984	0.60	0.30	0.80	0.80	0.80	0.00	0.00	0.80	1.00	1.00	0.80	0.80
1985	1.00	1.00	1.00	1.50	1.50	1.60	1.60	1.60	1.60	1.60	1.60	1.60
1986	1.60	1.80	1.80	1.90	1.80	1.80	1.80	1.90	1.90	1.90	**1.80**	

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GOVERNMENT STATISTICS

AUSTRALIA

	Price Index of Materials Used in Manufacturing Industry — All Groups[1] (1984 = 100)	Award Rates of Pay Indexes Australia — Adult Males In Mining Wage Earners, Weekly Rates[2] (1976 = 100)
1975 Avg.	150.4	132.6
1976 Avg.	168.4	160.9
1977 Avg.	192.0	179.0
1978 Avg.[3,4]	198.5	190.0
1979 Avg.	248.8	127.9
1980 Avg.	321.8	140.8
1981 Avg.	355.3	154.1
1982 Avg.[5]	368.6	174.9
1983 Avg.	401.6	181.8
FY84 Avg.[6]	95.3	—
FY85 Avg.[6]	100.0	—
Jan 1985	97.0	197.8
Feb 1985	98.6	197.8
Mar 1985	102.1	197.8
Apr 1985	104.4	202.8
May 1985	107.6	202.4
Jun 1985	108.7	202.4
Jul 1985	111.1	202.4
Aug 1985	110.5	202.4
Sep 1985	108.7R	202.5
Oct 1985	108.4R	202.4
Nov 1985	109.4R	209.9
Dec 1985	110.0R	210.0
Jan 1986	109.6R	210.0
Feb 1986	108.7R	210.0
Mar 1986	99.5R	210.5
Apr 1986	94.3R	210.5
May 1986	93.5R	210.5
Jun 1986	95.7R	210.5
Jul 1986	98.1	215.2
Aug 1986	98.2	215.2

P = Preliminary R = Revised since last month

[1]Australian Bureau of Statistics, Canberra: "Price Index of Materials Used in Manufacturing Industry" (Catalogue No. 6411.0). The basis of this index was revised to 1984 = 100. The previous index was 1969 = 100.

[2]Australian Bureau of Statistics, Canberra: "Award Rates of Pay Indexes, Australia" (Catalogue No. 6312.0). Figures for the latest fourteen months shown are subject to revision.

[3]Monthly data for 1970-78 appear on pages 4.7 and 4.8 of Report 138.

[4]Annual averages prior to 1979 reflect index base no longer in use.

[5]Monthly data for 1979-82 appear on page 35 of Report 184.

[6]Annual averages are for financial year ending June 30.

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CANADA

	Industry Selling Price Index: All Commodities[1] (1981 = 100)	Wage-earner Data: Average Hourly Earnings (C$)[2]					
		Uranium Mines (SIC 057)	Metal Mines (SIC 051-059)	Mines, Quarries and Oil Wells[3] (SIC 051-099)	Primary Non-ferrous Metal Industries[4] (SIC 296)	(SIC 298)	Chemicals and Chemical Products[5] (SIC 372-379)
1979 Avg.[6]	217.9	—	9.60	9.66	—	—	7.67
1980 Avg.	247.2	—	10.58	10.80	—	—	8.50
1981 Avg.	288.7	—	12.02	12.23	—	—	9.53
1982 Avg.[7]	288.8	—	13.74	13.92	—	—	10.63
1983 Avg.	298.8	—	—	14.30	—	—	11.17
1984 Avg.	310.9	17.88	—	15.07	12.28	10.49	11.76
Jan 1985	117.5	18.05	16.13	15.60	12.32	10.80	12.04
Feb 1985	117.7	18.78	16.41	15.68	12.52	11.05	12.06
Mar 1985	118.4	18.24	16.21	15.57	12.44	10.97	12.02
Apr 1985	118.3	18.63	16.44	15.80	12.81	11.23	12.04
May 1985	118.6	19.41	16.51	15.63	12.76	11.25	12.15
Jun 1985	118.6	18.49	16.20	15.49	12.89	11.14	12.14
Jul 1985	118.6	18.14	16.27	15.41	12.96	11.17	12.13
Aug 1985	118.4	17.07	16.03	15.30	12.97	11.31	12.19
Sep 1985	118.6	18.53	16.55	15.72	12.95	11.39	12.26
Oct 1985	119.0	18.74	16.51	15.70	13.14	11.53	12.33
Nov 1985	119.3	19.05	16.66	15.88	12.76	11.32	12.49
Dec 1985	120.0	19.07	16.57	16.01	12.51	11.09	12.59
Jan 1986	121.0	18.15	16.22	15.86	13.11	11.48	12.52
Feb 1986	120.8	19.52	16.57	15.99	13.20	11.59	12.45
Mar 1986	120.1	19.04	16.65	15.93	13.11	11.59	12.54
Apr 1986	119.3R	19.38	16.68	15.95	13.07	11.64	12.54
May 1986	118.6R	19.54	16.68	15.78	13.16	11.72	12.51
Jun 1986	118.6R	19.80	16.63	15.64	13.44	11.86	12.49
Jul 1986	118.7	19.51	16.34	15.48	13.28	11.73	12.52
Aug 1986	119.1	18.96P	16.13P	15.40	12.97P	11.78P	12.74P
Sep 1986	119.4P	—	—	—	—	—	—

P = Preliminary R = Revised since last month

[1]Statistics Canada, Prices Division, Ottawa: "Industry Price Indexes" (Catalogue 62-011). Indexes for the most recent six months shown are subject to revision. This category was formerly known as "Manufacturing." Index prior to 1985, 1971 = 100.

[2]Statistics Canada, Labour Division, Employment and Payrolls Section, Ottawa: "Employment, Earnings and Hours" (Catalogue 72-002).

[3]Reports 175 through 185 list this series title incorrectly as "Metal Mining, Including Milling (SIC 050-099)."

[4]Beginning with the April 1983 figure, Primary Metal Industries, non-ferrous is split into SIC 296 and SIC 298.

[5]Chemical and Chemical Products prior to April 1983 was SIC 370-379. The new series is from a new survey which includes all companies and is based on a 1970 classification. The old survey only included companies of 20 employees or more.

[6]Monthly ISPI for 1977 and 1978 appear on page 4.10 of Report 138, and monthly wage-earner data for 1973-78 appear on page 4.11 of Report 138.

[7]Monthly data for 1979-1982 appear on page 37 of Report 184. On that page, the wage earner index entitled "Metal Mining, Including Milling (SIC 050-099)" should read "Total Mining (SIC 051-099)."

[8]Beginning with the March 1983 figure, Wage Earner Data are based on a census of all companies employing 200 or more wage earners, *plus* a random survey of companies employing fewer than 200 wage earners. Prior to March 1983 only companies employing 200 or more wage earners are included in the Wage Earner Data.

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GOVERNMENT STATISTICS

REPUBLIC OF SOUTH AFRICA

		Average Declared Working Costs per Metric Ton of Gold Ore Milled (Rand)[1]	Tonnage-Weighted Index of Average Working Costs per Metric Ton of Gold Ore Milled (March 1982 = 100)[2]	Consumer Price Index[3] (1980 = 100)[4]	Producer Price Index All Groups[5] (1980 = 100)	Total Employment in Mining and Quarrying (Code 35)[6]	Total Salaries and Wages in Mining and Quarrying (1,000 Rand) (Code 40)[6]
1975	Avg.	16.71	—	157.2	100.0	639,473	1,003,617
1976	Avg.	19.30	—	174.7	115.1	671,240	1,212,983
1977	Avg.	23.87	—	194.4	130.0	712,006	1,420,670
1978	Avg.	27.14	—	137.2	142.7	664,571	1,537,169
1979	Avg.[7]	30.18	—	155.3	164.5	692,209	1,830,632
1980	Avg.[8]	35.53	—	176.7	192.1	714,379	2,279,615
1981	Avg.	41.89	—	206.5	218.3	728,506	2,820,505
1982	Avg.[9]	47.25	104.2	233.5	248.7	707,552	3,246,071
1983	Avg.	51.87	115.0	262.2	274.8	696,579	3,644,772
1984	Avg.	58.95	130.3	292.8	297.9	712,080	4,196,764
Jan	1985	—	—	177.1	166.6	711,366	376,777
Feb	1985	—	—	182.8	171.3	727,932	361,823
Mar	1985	64.48	142.4	183.6	173.0	708,809	371,380
Apr	1985	—	—	187.4	174.0	724,187	369,005
May	1985	—	—	189.5	177.7	708,085	373,478
Jun	1985	67.42	148.9	191.9	179.2	724,587	395,543
Jul	1985	—	—	193.6	180.7	738,228	419,106
Aug	1985	—	—	195.6	183.2	734,121	416,777
Sep	1985	70.47	155.3	197.8	184.8	732,836	419,883
Oct	1985	—	—	200.8	188.1	720,071	401,448
Nov	1985	—	—	203.4	196.0	750,049	432,996
Dec	1985	72.43	160.1	207.4	199.4	741,372	425,261
Jan	1986	—	—	213.8	203.6	744,070	449,513
Feb	1986	—	—	215.8	206.9	754,458	438,562
Mar	1986	75.76	167.8	218.3	206.9	759,897	445,387
Apr	1986	—	—	222.2	208.9	756,388	437,563
May	1986	—	—	222.6	212.5	754,788	425,544
Jun	1986	77.65	172.0	224.4	213.3	756,637	462,365
Jul	1986	—	—	228.8	216.3	756,140R	516,832R
Aug	1986	—	—	232.2	220.3	760,925	502,968
Sep	1986	81.94P	181.8	236.7	221.9	—	—
Oct	1986	—	—	239.3	—	—	—

P = Preliminary R = Revised since last month

[1]Chamber of Mines of South Africa, Johannesburg: "Analysis of Working Results," published quarterly.

[2]Page 16 of Report 178 contains description and calculation of index, and page 24 of Report 178 lists figures for 1982.

[3]Republic of South Africa Department of Statistics, Pretoria: "Government Gazette: Consumer Price Index for Urban Areas."

[4]The basis for calculation prior to January 1985, 1975 = 100. For annual averages prior to 1978, April 1970 = 100.

[5]Previously known as the Wholesale Price Index, now the Producer Price Index. The computation remains the same. The basis for calculation prior to January 1985, 1975 = 100.

[6]Bulletin of Statistics, Department of Statistics, Pretoria.

[7]Historical data for the Average Declared Working Costs and Consumer Price Index 1970-1979 appear on page 4.9 of Report 140.

[8]Monthly data for Codes 35 and 40, 1977-1980, appear on page 28 of Report 157.

[9]Monthly data for 1979-82 appear on page 39 of Report 184.

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UNITED STATES

	Producer Price Index[1]		Consumer Price Index[2]	GNP Implicit Price Deflator[3,4]	Gross Average Hourly Earnings of Production or Non-supervisory Workers (US$)[5]			
	Industrial Commodities (1967 = 100)	All Commodities (1967 = 100)	(1967 = 100)	(1982 = 100)	Metal Mining (SIC 10)	Primary Non-ferrous Metals (SIC 333)	Chemicals and Allied Products (SIC 28)	Electric and Electronic Equipment (SIC 36)
1980 Avg.[6]	274.8	268.8	246.8	178.64	10.26	10.63	8.30	6.94
1981 Avg.	304.1	293.4	272.4	195.51	11.55	11.98	9.12	7.62
1982 Avg.[7]	312.3	299.3	289.1	207.15	12.33	12.94	9.96	8.21
1983 Avg.	315.8	303.1	298.4	215.63	12.57	13.43	10.59	8.65
1984 Avg.	322.6	310.3	311.1	108.1	13.05	13.43	11.08	9.04
Jan 1985	322.9	309.5	316.1	—	13.29	13.70	11.39	9.33
Feb 1985	322.5	309.2	317.4	—	13.30	13.73	11.39	9.33
Mar 1985	322.6	308.7	318.8	110.4	13.29	13.95	11.37	9.39
Apr 1985	323.8	309.3	320.1	—	13.43	13.63	11.47	9.40
May 1985	325.3	309.8	321.3	—	13.24	13.60	11.44	9.39
Jun 1985	324.8	309.2	322.3	111.3	13.23	13.68	11.51	9.46
Jul 1985	324.4	309.0	322.8	—	13.45	13.83	11.59	9.47
Aug 1985	323.7	307.3	323.5	—	13.55	13.71	11.60	9.50
Sep 1985	322.3	305.5	324.5	112.1	13.44	13.68	11.65	9.54
Oct 1985	324.2	307.9	325.5	—	13.49	13.66	11.70	9.55
Nov 1985	324.7	309.5	326.6	—	13.49	13.97	11.80	9.61
Dec 1985	325.1	310.2	327.4	113.0	13.43	13.81	11.85	9.68
Jan 1986	323.8	308.9	328.4	—	13.40	13.69	11.86	9.60
Feb 1986	318.9	304.4	327.5	—	13.44	13.82	11.81	9.60
Mar 1986	314.0	300.3	326.0	113.5	13.38	13.93	11.78	9.62
Apr 1986	311.6	298.2	325.3	—	13.54	13.87	11.82	9.62
May 1986	311.6	299.2	326.3	—	13.46	13.79	11.89	9.64
Jun 1986	311.8R	299.0R	327.9	114.2	13.52	13.49	11.94	9.61
Jul 1986	308.5	297.7	328.0	—	13.47	13.22	12.04	9.68
Aug 1986	307.7	297.2	328.6	—	13.04R	13.18R	11.99R	9.67
Sep 1986	308.8	297.7	330.2	115.0	13.14P	13.43P	12.00R	9.72R
Oct 1986	309.3	298.3	330.5	—	—	—	12.09P	9.67P

P = Preliminary R = Revised since last month

[1]US Bureau of Labor Statistics, Washington, D.C.: "Producer Prices and Price Indexes," (formerly "Wholesale Prices and Price Indexes"). Producer Price Indexes are revised four months after they are first released to reflect the availability of late reports and corrections by respondents.

[2]US Bureau of Labor Statistics, Washington, D.C.: Consumer Price Index for All Urban Consumers, US City Average, All Items.

[3]US Department of Commerce, Washington, D.C.: Bureau of Economic Analysis, National Income and Wealth Division: "Survey of Current Business." The GNP Implicit Price Deflator is published quarterly, and seasonally adjusted.

[4]The basis for calculation of this index was revised to 1982 = 100. 1984 and 1985 figures have been adjusted to that basis. The basis for calculation prior to 1984, 1972 = 100.

[5]US Bureau of Labor Statistics, Washington, D.C.: "Employment and Earnings." All data based on 1972 revision of SIC Manual. Data for 1970-1976 are adjusted to the March 1977 benchmark. Data for 1977-1978 are adjusted to the March 1979 benchmark. Data for January 1979 and beyond are adjusted to the March 1980 benchmark.

[6]Monthly data 1970-1978 for Producer Price Index-Industrial Commodities, Consumer Price Index, and Employment and Earnings SIC codes 10, 333, and 28, and quarterly data for GNP Implicit Price Deflator appear on pages 4.6-4.8 of Report 139.
Monthly data 1977-1978 for Employment and Earnings SIC Codes 10, 333, and 28 appear on page 33 of Report 147.
Monthly data 1970-1978 for Employment and Earnings SIC Code 36 appear on page 23 of Report 154.
Monthly data 1977-1980 for Producer Price Index-All Commodities, appear on page 21 of Nuexco Report 158.

[7]Monthly data 1979-1982 for all listed indices appear on page 41 of Report 184.

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